THE MECHANISM IN THE HATCHING OF THE WALKING STICK, DIAPHEROMERA FEMORATA SAY.

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(WITH PLATE XIV.)

In the Phasmidae, Mantidae, Blattidae and Acridiidae, the cervical ampulla is said to play an inportant role in the process of molting, and in some Orthoptera, also in the process of hatching. This ampulla, consisting of a soft membrane joining the head dorsally to the prothorax, can be transformed by the afflux of blood into a greatly swollen pouch, which then projects out immediately behind the head.

The process of hatching of various Orthoptera has been studied by a number of entomologists. Riley (7) does not mention the cervical ampulla while describing the phenomenon of hatching in the Rocky Mountain Locust, for he writes as follows: "The hatching consists of a continued series of undulating contractions and expansions of the several joints of the body, and with this motion there is slight but constant friction of the tips of the jaws and of the sharp tips of the hind tibial spines, as also of the tarsal claws of all the legs against the shell, which eventually weakens and finally gives away. It then easily splits up to the eyes or beyond, by the swelling of the head."

Packard (5) objects to Riley's account of the supposed action of the jaws and spines and believes that "the egg-shell is without doubt burst open by the puffing out or expansion of the membrane connecting the head and prothorax, just as the common house-fly or flesh-fly bursts off the end of its pupa-case by the puffing out of the front of the head."

Kunckel d'Herculais (3 and 4) gives the following account of the physiological mechanism in the hatching of the Acridiidae: "Les Acridiens rompent la coque de l'oeuf, * * * par la pression exercee a l'aide de la membrane unissant dorsalement la tête au prothorax que se transforme par afflux de sang en une ampoule cervicale."

In Diapheromera femorata the mechanism, which ruptures the various membranes and springs off the operculum when the walking-stick is about to emerge from the egg, cannot be observed in action on account of the hard, thick, opaque chorion. If the operculum is carefully removed from an egg shortly

before hatching, the embryo will be found with its head and prothorax situated directly beneath the portion of the egg removed (Fig. 1, *h* and *p*). The pressure exerted by the cervical ampulla is, therefore, directly against the operculum.

Hatching spines for the purpose of rupturing the embryonic envelopes and also for breaking or cutting open the egg-shell have been described from many insect eggs. Above the prothorax of Diapheromera, the thin amnion is covered by numerous long spines which point toward the operculum. These spines, like the egg-burster (or *ruptor ovi* as Riley (6) calls it) of Corydalus cornutus, are portions of the amnion itself. If the prothorax of a walking-stick is examined after its emergence from the egg, no spines are found, but simply short blunt protuberances. In all probability, the long spines of the amnion above the prothorax assist in rupturing the vitelline membrane which is especially thick beneath the operculum.

"When the young walking-stick is in the egg, ready to emerge, the meso- and metathorax are not remarkably elongate, but before the little creature is fairly out of its narrow prison, the thoracic segments assume their usual proportions. It is said to be a most curious sight by those who have observed this almost instantaneous development." (Caudell [2]).

An attempt was made by us to secure an explanation for this curious phenomenon observed by Caudell. After the chorion of the egg was removed, the embryo was found to be so curled up in the egg that the posterior end of the abdomen lay near the head region. A longitudinal section through the embryo showed that the thorax was folded transversely in a dorso-ventral direction (Fig. 2). In all probability it is simply the straightening out of these folds as the young walking-stick emerges, that causes the thoracic segments to assume their usual proportions. If the pressure exerted by the cervical ampulla at the time of hatching is not sufficient to rupture the amniotic and vitelline membranes and also to throw off the operculum, it may be possible that the straightening out of some of these thoracic folds assist in the process.

After pushing off the operculum, the young walking-stick, with the prothorax bent down at its union with the mesothorax, begins to emerge from the egg (Fig. 3). The cervical ampulla is now slightly swollen, and the prothorax possesses a deep green color, due to the blood which has accumulated within it.

The method employed during the process of emerging from the egg is almost identical with that which we (10) have described of a walking-stick withdrawing itself from its old skin during the process of ecdysis. A specimen examined under a binocular microscope during the process of emergence from the egg, will be seen to undergo a series of peristaltic-like movements of the segments of the body; these movements pass from the posterior end of the abdomen towards the head. With each series of these movements, the body is drawn out of the egg-shell a short distance, the legs also assisting somewhat in this process of extraction. At each pull of the legs in their attempted withdrawal from the egg-capsule, the strength of the pull is such, that the coxa of each leg presses against the body, causing in that region a temporary indentation. When the peristaltic-like movements reach the head, the walking-stick often raises the head vigorously upward in an attempt to withdraw the antennae.

The first part of the walking-stick to leave the egg is the dorsal surface of the prothorax (Fig. 3, *p*); then comes the head (Fig. 3, *h*), followed by the rest of the thorax. The antennae are freed next, and these may come forth either simultaneously or one soon followed by the other. The following order was often observed in the withdrawal of the legs: one middle leg was followed by the other; then the front legs were pulled out of the egg at the same time, and finally the hind legs. The abdomen does not leave the egg at any definite time in relation to the withdrawal of the other parts, but it may emerge after the antennae or, in other specimens, after the middle or front legs. The extrication of the antennae, legs and abdomen, however, does not always take place in the order just given, as is shown in the following table:

TABLE I.

Order of Withdrawal of the Antennae, Legs and Abdomen from the Eggs of Six Diapheromera femorata.

A	B	C	D	E	F
{antenna	antenna	antenna	middle leg	abdomen	abdomen
{antenna	antenna	antenna	antenna	{antenna	antenna
front leg	middle leg	abdomen	middle leg	{antenna	antenna
middle leg	abdomen	middle leg	antenna	middle leg	middle leg
middle leg	middle leg	middle leg	abdomen	front leg	middle leg
front leg	front leg	front leg	front leg	front leg	front leg
abdomen	front leg	front leg	front leg	{middle leg	front leg
{hind leg	{hind leg	hind leg	{hind leg	{hind leg	hind leg
{hind leg	{hind leg	hind leg	{hind leg	hind leg thrown off.	hind leg

Braces indicate that the two included appendages were extricated simultaneously.

Stockard (11) describes the hatching of Aplopus mayeri as follows: "When hatching the embryo's head and body come forth from the egg first, the antennae are then pulled out, the legs being the last parts liberated from the shell." The specimens noted under E and F in the above table agree with Stockard's observations on Aplopus, but both of these specimens had their appendages caught in the amniotic membrane (Fig. 4). In a previous paper we (9) have already called attention to the fact that dryness, at the time of hatching, has a marked effect upon the emergence of the walking-stick from the egg. With the addition of water which was added drop by drop to the egg-shell, within which the above-mentioned specimens were caught, these walking-sticks succeeded in freeing themselves.

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EXPLANATION OF PLATE XIV.

All figures were drawn with a camera lucida.

FIG. 1. View of embryo after the operculum has been removed showing the head and prothorax directly beneath. The pressure exerted by the cervical ampulla, which joins the head dorsally to the prothorax, would be directly against the operculum: *h*, head; *p*, prothorax; *vi*, vitelline membrane; *c*, compound eyes.

FIG. 2. Longitudinal section through the head and thorax of the embryo, showing the transverse folding of the thorax in a dorso-ventral direction; *h*, head; *p*, prothorax; *m*, mesothorax; *met*, metathorax.

FIG. 3. Walking-stick emerging from the egg, showing that the prothorax is bent down at its union with the mesothorax: *h*, head; *p*, prothorax; *m*, mesothorax; *op*, operculum still adhering to the egg by means of the so-called "shell membrane."

FIG. 4. Walking-stick with its appendages caught within the egg-shell: *ha*, "hilar area."